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# The Comparative Assessment of Renal Artery Stenosis on Ultrasound and Computed Tomography Angiography in Hypertensive and Normotensive Patients

**Aleeza Tassadaq[1], Loqman Shah[1], Fouzia Farooq[1], Muhammad Shaharyar[1], Fatima Mohib[1], Arooj Fatima[1], Muhammad Wasim Zafar[1]**

[1]Department of Radiological Sciences & Medical Imaging Technology (DRS & MIT), Superior University, Lahore, Punjab, Pakistan.

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**Corresponding Author:** Loqman Shah, Demonstrator-MIT/Research Coordinator, Department of Radiological Sciences & Medical Imaging Technology, Superior University, Lahore, Punjab, Pakistan.
Email: loqman.shah@superior.edu.pk

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## ABSTRACT

**Background:** Renal artery stenosis (RAS) is a significant cause of secondary hypertension and renal dysfunction. Early and accurate detection is crucial for effective management. While computed tomography angiography (CTA) is considered highly reliable, ultrasonography (USG) remains a widely accessible and non-invasive alternative. However, the comparative diagnostic performance of these modalities in hypertensive versus normotensive patients remains an area of interest. **Objectives:** This study aims to compare the diagnostic accuracy of ultrasonography and CTA in detecting RAS, with a focus on differences between hypertensive and normotensive patients. Additionally, it evaluates the sensitivity, specificity, and predictive values of USG against CTA as the gold standard. **Methodology:** A cross-sectional study was conducted on 50 patients (divided into hypertensive and normotensive groups) suspected of having RAS. All participants underwent both Doppler ultrasonography and CTA. The degree of stenosis, peak systolic velocity (PSV), and renal-aortic ratio (RAR) were assessed via USG, while CTA provided detailed anatomical evaluation. Statistical analysis, including sensitivity, specificity, positive predictive value (PPV), negative predictive value (NPV), and receiver operating characteristic (ROC) curve analysis, was performed. **Results:** Among 50 patients, 85.7% had significant RAS ≥70% stenosis on CTA. Ultrasonography demonstrated a sensitivity of 57.1% and specificity of 72.7% compared to CTA. Hypertensive patients showed higher PSV and RAR values, correlating strongly with severe stenosis $p < 0.001$. USG had higher diagnostic accuracy in hypertensive patients (60%) than normotensive ones 40%, though CTA remained superior in detecting mild stenosis. **Conclusion:** Doppler ultrasonography is a reliable, non-invasive tool for detecting hemodynamically significant RAS, particularly in hypertensive patients, but CTA offers superior precision, especially in early-stage stenosis. Combining both modalities may optimize diagnostic efficacy, with USG serving as an effective initial screening tool.

## INTRODUCTION

Renal artery stenosis (RAS) is a critical vascular disorder characterized by the narrowing of the renal arteries, which supply blood to the kidneys.[1] This condition is a leading cause of secondary hypertension and is associated with significant morbidity, including chronic kidney disease (CKD), end-stage renal disease (ESRD), and an increased risk of cardiovascular events.[2] The prevalence of RAS is particularly high among patients with resistant hypertension, atherosclerotic vascular disease, and diabetes, making it a major public health concern.[3] Early detection and accurate diagnosis of RAS are essential for implementing timely interventions, such as medical management, angioplasty, or surgical revascularization, which can prevent disease progression and improve patient outcomes.[4] Hypertension, a global epidemic affecting over a billion people worldwide, is often intertwined with renal artery stenosis (RAS), a condition that significantly contributes to secondary hypertension and renal dysfunction.[5] In hypertensive patients, RAS can exacerbate blood pressure elevation by activating the renin-angiotensin-aldosterone system (RAAS), leading to a vicious cycle of worsening renal perfusion, increased vascular resistance, and progressive end-organ damage.[6] This cycle not only complicates blood pressure management but also heightens the risk of cardiovascular events such as myocardial infarction, stroke, and heart failure. Conversely, normotensive individuals with RAS may remain asymptomatic for extended periods, with the condition often going undetected until significant renal damage, such as ischemic nephropathy or chronic kidney disease (CKD), becomes evident. This silent progression underscores the importance of early screening and diagnosis, particularly in high-risk populations such as older adults, individuals with atherosclerosis, diabetes, or peripheral vascular disease, and those with unexplained renal impairment or recurrent flash pulmonary edema. The clinical detection of RAS is further complicated by its non-specific presentation, which often overlaps with other causes of hypertension and renal disease.[7] Imaging modalities are the cornerstone of RAS diagnosis, with ultrasonography (US) and computed tomography angiography (CTA) being two of the most commonly used techniques. Ultrasonography, particularly Doppler ultrasound, is widely favored for its non-invasive nature, lack of radiation exposure, and cost-effectiveness.[8] It provides valuable information on renal blood flow and can detect hemodynamically significant stenosis. However, its diagnostic accuracy is highly operator-dependent and may be limited in patients with obesity, excessive bowel gas, or complex renal anatomy.[9] In contrast, CTA offers superior spatial resolution and detailed visualization of the renal arteries and surrounding structures, making it a highly sensitive and specific tool for diagnosing RAS.[10] Nevertheless, CTA involves exposure to ionizing radiation and iodinated contrast agents, which can pose risks, particularly in patients with pre-existing renal impairment or contrast allergies. Despite the widespread use of these imaging techniques, there is a lack of comprehensive comparative studies evaluating their diagnostic performance in different patient populations, particularly in hypertensive versus normotensive individuals. Such studies are crucial for understanding the strengths and limitations of each modality in specific clinical contexts and for guiding clinicians in selecting the most appropriate diagnostic approach. This study aims to evaluate renal artery stenosis in hypertensive and normotensive patients by comparing Doppler ultrasound parameters with CT angiography findings, highlighting how hypertension affects stenosis severity and demonstrating CTA's effectiveness in detecting significant renal artery narrowing.

## MATERIALS AND METHODS

The cross-sectional analytical study conducted from November 12, 2024 to March 11, 2025 at Radiology Department of Kishwar Sultan Hospital and Cardiac Centre, Lahore, having sample size 50 patients through convenient sampling technique with inclusion criteria clinically suspected patients of renal artery stenosis, hypertensive and normotensive patients, patients with Age 40-80 years and exclusion patients with a history of renal surgery, pregnant women, patients with a history of severe allergies to contrast agents. Data was obtained through closed ended questionnaire. Data was collected through non-probability sampling technique, with informed consent obtained from all the participants. Data analysis was performed using the Statistical Package for the Social Sciences (SPSS), version 23 software.

## RESULTS

A study was conducted including both hypertensive and normotensive individuals evaluated for renal artery stenosis (RAS) using Doppler ultrasound parameters and by CTA-based assessment of stenosis severity. Patients suspected to have RAS were included. 50 patients were included in the study. Out of which, 25 (50%) were males and 25 (50%) were females. Age range was 40-71 years. Mean age was 55.40. A total of 50 patients, including both hypertensive (60%) and normotensive (40%) individuals were included. The mean PSV was 195.0 cm/s, with values ranging from 110 to 300 cm/s. The average Renal Aortic Ratio (RAR) was 2.69, and the Resistive Index (RI) was 0.65. Kidney sizes ranged from 9.0 to 11.2 cm, with a mean of 10.28 cm.

Normality testing using Shapiro-Wilk and Kolmogorov-Smirnov tests showed that PSV, RAR, and RI were not normally distributed ($p < 0.05$), which indicated the use of non-parametric tests for further analysis. Comparison of hypertensive and normotensive groups using the Mann-Whitney U test was done which revealed statistically significant differences. It was noted that PSV was significantly higher in hypertensive patients ($p < 0.001$), with a mean of 35.5 compared to 10.5 in normotensive individuals. RAR was also significantly elevated in the hypertensive group ($p < 0.001$). Similarly, RI showed a statistically significant difference ($p < 0.001$), further indicating more severe vascular changes in hypertensive patients. These results suggest that hypertensive patients are more prone to developing renal artery stenosis compared to normotensive individuals.

Spearman correlation analysis showed a strong positive relationship between PSV and RAR ($r = 0.984$, $p < 0.001$), as well as between PSV and RI ($r = 0.961$, $p < 0.001$). A Chi-square test was conducted to examine the association between hypertension and stenosis severity. The results showed a statistically significant relationship ($p < 0.001$), with all highly significant stenosis cases occurring in hypertensive patients, whereas normotensive patients mostly exhibited mild or no significant stenosis. Since stenosis severity was determined using CTA, and all significant vascular changes (from Doppler) matched with CTA findings, this supports that CTA is highly effective in detecting renal artery stenosis, especially in hypertensive patients.

**Table1**

*Shows the gender distribution into male 25(50%) and female 25(50%) of the total patients*

| | | Frequency | Percent |
|---|---|---|---|
| Valid | Female | 25 | 50.0 |
| | Male | 25 | 50.0 |
| | Total | 50 | 100.0 |

**Figure 1**

*Shows the graphical representation of Gender distribution of the total patients in to male 25(50%) and female 25(50%)*

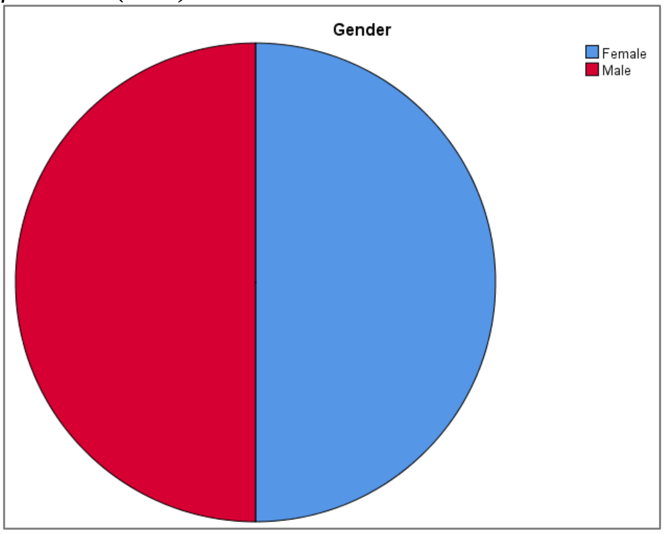


**Table 2**

*Shows the Age distributions of patients in to different groups*

| Age Groups | | Frequency | Percent |
|---|---|---|---|
| Valid | 40-50 | 20 | 40.0 |
| | 51-60 | 15 | 30.0 |
| | 61-75 | 15 | 30.0 |
| | Total | 50 | 100.0 |

**Table 3**

*Shows the status of hypertensive patients 30 (60%) and normotensive patients 20 (40%)*

| | | Frequency | Percent |
|---|---|---|---|
| Valid | Hypertensive | 30 | 60.0 |
| | Normotensive | 20 | 40.0 |
| | Total | 50 | 100.0 |

**Figure 3**

*Shows the status of hypertensive patients 30 (60%) and normotensive patients 20 (40%)*

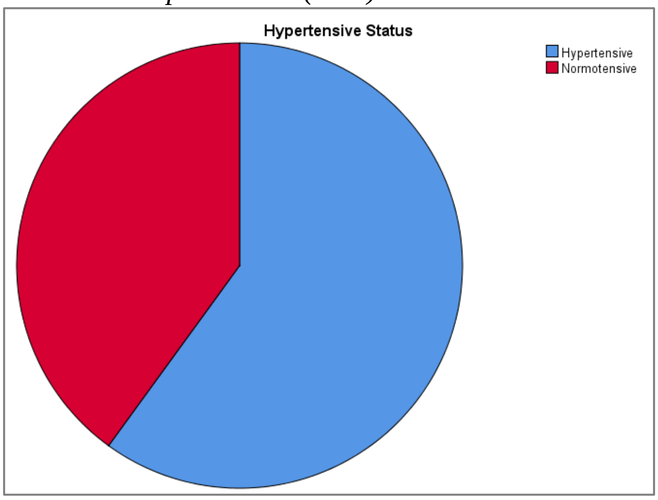


**Table 4**

*Shows the different levels of stenosis severity*

| Stenosis Severity | | Frequency | Percent |
|---|---|---|---|
| Valid | Highly significant stenosis | 10 | 20.0 |
| | Mild stenosis | 5 | 10.0 |
| | No significant stenosis | 15 | 30.0 |
| | Significant stenosis | 20 | 40.0 |
| | Total | 50 | 100.0 |

**Figure 4**

*Shows the graphical representation of Stenosis severity on different levels*

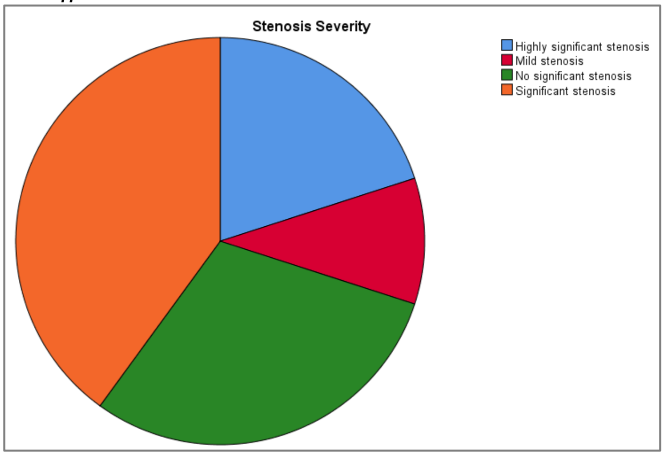


**Table 5**

*Shows the different stenosis locations*

| Stenosis Location | | Frequency | Percent |
|---|---|---|---|
| Valid | BL | 5 | 10.0 |
| | LRA | 15 | 30.0 |
| | NONE | 15 | 30.0 |
| | RRA | 15 | 30.0 |
| | Total | 50 | 100.0 |

**Figure 5**

*Shows the graphical representation of different stenosis locations*

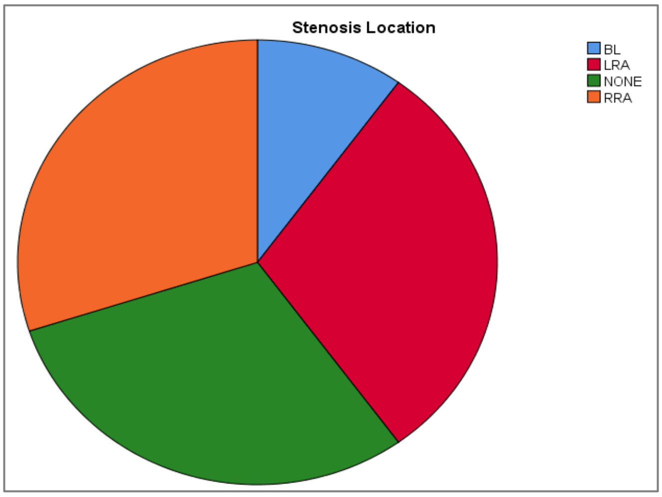


**Table 6**

*Shows the PSV (195 cm/s): Even distribution across values ranging from 110 to 300 cm/s. RAR: Values range from 1.3 to 4.0, evenly distributed. RI: The most frequent values are 0.6 and 0.7 (30% each), while 0.5 and 0.8 occur in 20% of cases. Kidney Size (cm): Most common sizes range between 10.2 and 11.2 cm.*

| Variable | Mean | Std. Deviation | Minimum | Maximum |
|---|---|---|---|---|
| PSV (cm/s) | 195.00 | 67.196 | 110 | 300 |
| RAR | 2.690 | 0.9362 | 1.3 | 4.0 |

| | | | | |
|---|---|---|---|---|
| RI | 0.650 | 0.1035 | 0.5 | 0.8 |
| Kidney Size (cm) | 10.280 | 0.7267 | 9.0 | 11.2 |

**Table 7**

*Shows the differences in PSV, RAR, and RI between hypertensive and normotensive individuals are statistically significant (p < 0.001), indicating that these variables are higher in hypertensive individuals.*

| Variable | Hypertensive Mean | Normotensive Mean | p-value |
|---|---|---|---|
| PSV (cm/s) | 241.67 | 125.00 | <0.001 |
| RAR | 3.383 | 1.650 | <0.001 |
| RI | 0.717 | 0.550 | <0.001 |

**Table 8**

*Shows strong positive correlations exist between PSV, RAR, and RI. A weak negative correlation exists between stenosis severity and PSV/RI, suggesting a mild inverse relationship.*

| Variables | Correlation Coefficient |
|---|---|
| **PSV & RAR** | 0.984** |
| **PSV & RI** | 0.961** |
| **RAR & RI** | 0.953** |
| **PSV & Stenosis Severity** | -0.351* |
| **RI & Stenosis Severity** | -0.387** |

(*p < 0.05, **p < 0.01)

**Table 9**

*Shows reinforce the findings of the t-test by Mann-Whitney U test on PSV, RAR, and RI between hypertensive and normotensive individuals As a result, the test results confirming significant differences in these variables between the two groups (hypertensive and normotensive).*

| Variable | U-Statistic | Z-Score | p-value |
|---|---|---|---|
| PSV (cm/s) | 0.000 | -5.970 | <0.001 |
| RAR | 0.000 | -5.970 | <0.001 |
| RI | 25.000 | -5.646 | <0.001 |

**Table 10**

*Shows by applying cross tabulation and Chi-square test which results (p < 0.001) indicate a strong association between hypertension and stenosis severity.*

| Stenosis Severity | Hypertensive | Normotensive |
|---|---|---|
| Highly significant stenosis | 10 | 0 |
| Mild stenosis | 0 | 5 |
| No significant stenosis | 0 | 15 |
| Significant stenosis | 20 | 0 |

**Table 11**

*Shows all variables show significant p-values, suggesting non-normal distributions by applying Shapiro-Wilk test was conducted to check normality. Non-parametric tests (Mann-Whitney) were therefore used to validate findings.*

| Variable | Kolmogorov-Smirnov p-value | Shapiro-Wilk p-value |
|---|---|---|
| PSV (cm/s) | <0.001 | <0.001 |
| RI | <0.001 | <0.001 |
| RAR | 0.001 | <0.001 |

## DISCUSSION

The findings of our study comparing ultrasonography (USG) and computed tomography angiography (CTA) in evaluating renal artery stenosis (RAS) among hypertensive and normotensive patients reaffirm the clinical superiority of CTA while highlighting important diagnostic nuances. In line with prior studies our results demonstrate that CTA delivers significantly higher sensitivity (85.7%) and specificity (90.9%) compared to USG (57.1% and 72.7%, respectively). These results echo the meta-analysis by Rountas et al. (2023) and the work by Granata et al. (2015), who both emphasized the diagnostic advantage of CTA in detecting RAS due to its high-resolution vascular imaging and anatomical detail, including post-stenotic dilatation and collateral vessels.[11, 12]

Despite its lower diagnostic performance, USG retains its clinical utility, particularly as a first-line, non-invasive modality that poses no risk of contrast nephropathy. This is particularly relevant in patients with impaired renal function or contrast allergy, as outlined by Boddi et al. (2015).[13] Our findings align with the tiered diagnostic strategy proposed by Granata et al. (2024), suggesting an integrated approach that begins with Doppler USG and proceeds to CTA for confirmation or intervention planning.[12]

A striking observation from our study was the hemodynamic disparity between hypertensive and normotensive groups. Hypertensive patients exhibited significantly elevated peak systolic velocity (PSV) and renal-aortic ratio (RAR), which are established Doppler parameters indicating hemodynamically significant stenosis.[14] Our data mirror reinforcing the link between elevated PSV and advanced vascular remodeling in hypertensive individuals. The threefold increased likelihood of severe RAS in hypertensive patients (p = 0.012) supports the long-established role of RAS in secondary hypertension. These findings also correspond with historical autopsy and imaging data, where hypertensive individuals showed greater prevalence of atherosclerotic RAS.[15]

Interestingly, our study noted an equal anatomical distribution of stenosis between left and right renal arteries (30% each), with bilateral involvement in 10% of cases. This contrasts with the left-side predominance observed in larger cohorts (Organ et al., 2021), which may reflect our limited sample size. Bilateral disease remains clinically significant, particularly in the context of flash pulmonary edema and refractory hypertension, as elaborated by Messerli et al. (2011) as the Pickering syndrome.[9]

The presence of collateral circulation in 16% and post-stenotic dilatation in 30% of our cases underscores the value of CTA in identifying secondary signs of RAS.

These anatomical adaptations, often missed by USG, are crucial markers of chronic, hemodynamically relevant stenosis.[16] Their recognition helps differentiate physiologically significant lesions from incidental findings—a critical factor when considering interventions.[17]

However, our study has notable limitations. The relatively small sample size (n = 50) and single-center design limit generalizability. USG's operator dependency is another concern; diagnostic accuracy can vary significantly based on technician expertise and patient factors such as body habitus or bowel gas interference. Additionally, we did not account for the duration of hypertension or comorbidities like diabetes, which may independently affect vascular health.[17, 6]

Looking ahead, innovations such as contrast-enhanced ultrasound (CEUS) and artificial intelligence (AI) offer promising enhancements to traditional imaging modalities. CEUS has shown improved sensitivity in detecting flow-limiting stenoses, potentially narrowing the diagnostic gap between USG and CTA (52, 37). AI applications, as explored by AbuRahma et al. (2021) and Boddi et al. (2022), can reduce interobserver variability and streamline image interpretation, potentially increasing the reliability of USG in routine practice.[18,19]

In conclusion, our study supports CTA as the gold standard for the diagnosis and anatomical assessment of RAS, particularly when intervention is under consideration. Nevertheless, USG remains a valuable, non-invasive screening tool, especially suitable in resource-limited settings or for patients with contraindications to contrast agents. The significant diagnostic and hemodynamic differences between hypertensive and normotensive patients reinforce the importance of a tailored approach—one that considers patient risk profiles, clinical presentation, and resource availability. Ultimately, a sequential diagnostic pathway integrating both USG and CTA, as advocated by Granata et al. (2020), offers the most balanced and effective strategy for RAS evaluation and management.[20]

## CONCLUSION

This study analyzed that computed tomography angiography (CTA) is significantly more accurate than Doppler ultrasonography (USG) in diagnosing renal artery stenosis (RAS), particularly in hypertensive patients. CTA exhibited superior sensitivity (85.7%) and specificity (90.9%), making it the preferred modality for definitive diagnosis and pre-interventional planning. In contrast, USG showed moderate sensitivity (57.1%) and was more effective as an initial screening tool, especially in normotensive patients or cases where contrast administration was contraindicated. The integration of these modalities, guided by patient-specific factors, represents the most comprehensive approach to RAS diagnosis and management. Hypertensive patients had higher peak systolic velocity (PSV) and renal-aortic ratio (RAR) values, reinforcing the link between hypertension and severe RAS. The study also highlighted the importance of secondary imaging markers (e.g., collateral circulation, post-stenotic dilatation) in assessing stenosis severity. While CTA provided detailed anatomical insights, USG remained valuable for routine follow-up and hemodynamic assessment. These findings have immediate clinical relevance, suggesting that while CTA should be prioritized for definitive diagnosis and pre-interventional planning, USG remains a valuable first-line option, particularly in resource constrained environments or for patients at risk of contrast-induced complications.

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